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Factors Affecting the Heat Coagulation of Homog- enized Coffee Cream

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UNIVERSITY OF ILLINOIS
AGRICULTURAL EXPERIMENT STATION
BULLETIN 352

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Factors Affecting the Heat Coagulation of Homogenized Coffee Cream

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IN MANY milk plants it is a common practice to homogenize^a the light cream sold for table use. The purpose of this process is to give the cream a heavier body, and to prevent the formation of a cream plug or a visible cream layer at the top of the bottle. The pressure to which the cream is subjected in the homogenizer causes a subdivision of the fat globules so that they are less able to respond to the force of gravity which normally causes them to rise. There also results an increase in the surface area of the fat globules as well as an increase in the amount of adsorbed protein. There is a tendency for the newly formed fat globules to come together into clusters, the extent of clustering depending upon the homogenizing temperature and pressure and, as Doan^{3*} has pointed out, upon the ratio of fat to serum solids in the cream.

It is apparent that to accomplish the desired results, a certain minimum homogenizing pressure is necessary. Excessive pressures have been thought to be a contributory factor to the curdling of the cream when mixed with hot coffee. It has become the usual practice, therefore, to homogenize the cream at a pressure between 300 and 1,500 pounds at pasteurizing temperatures.

Some study has been made of the coagulation, or feathering, of cream in coffee. Burgwald^{1*} found the acidity of the cream and the homogenizing pressure to be the controlling factors in producing feathering. Webb and Holm^{11*} concluded that feathering of cream was mainly a problem of quality. They also concluded that "pure, fresh cream of 20 percent butterfat content and .15 percent acidity can generally be pasteurized from 65° to 85° C., and homogenized at any pressure up to 3,000 pounds without danger of feathering." A preliminary investigation^{9*} made in a plant experiencing periodic occurrences of cream feathering led the authors to believe, however, that in some cases fresh cream of normal acidity, homogenized even at low pressures, would feather. It was in order to obtain an explanation for this situation that the present study was made.

PLAN OF THE EXPERIMENTS

It was thought that the feathering of cream represented a type of reaction not unlike that of the heat coagulation of evaporated milk.

*As used in this discussion, the terms homogenize and viscolize are synonymous.

With this in mind it was planned to study the significance of such variables as the mineral content of the water used for making the coffee; the salt balance of the cream serum; the temperature to which the cream is heated before homogenization; the temperature and pressure of homogenization; double homogenization, or the use of the second valve; and the fat and serum solids content of the cream. The importance of each factor was determined by its effect upon the amount of feathering, or coagulum, formed. In most cases this was measured volumetrically in 100-cc. graduates, using a 9-gram sample of cream and 100 cc. of water having a temperature of approximately 205° F., the mixing being done in a teacup.

EXPERIMENTAL RESULTS

Feathering of Cream in Hard Water

The nature of the mineral content of water depends upon the kind of strata thru which the water has passed. In some localities the water supply contains dissolved mineral salts. In the preliminary study referred to above, it was found that fresh cream homogenized at low pressures, when mixed with the local water at boiling temperatures, would often feather. For example, in one case feathering was found to occur in cream containing 18.07 percent fat, 26.01 percent total solids, and .13 percent acidity, that had been homogenized at 500 pounds pressure. However, when water from a well located in another community or when distilled water was used, no feathering was apparent, even with the cream homogenized at 3,000 pounds pressure.

When the water which caused feathering was run thru a water softener of the Zeolite type, no curdling resulted from its use, even with cream homogenized at high pressures. It was noted that boiling this water for a few minutes to remove the temporary hardness reduced the amount of feathering.

Following is an analysis made by the Illinois State Water Survey of a sample of water from the same wells as the water used in these experiments.

Determinations made	Parts per million	Determinations made	Parts per million
Iron, Fe.....	.8	Sodium, Na.....	16.4
Manganese, Mn.....	.0	Potassium, K.....	4.9
Silica, SiO ₂	8.9	Sulfate, SO ₄	292.0
Nonvolatile.....	3.6	Nitrate, NO ₃	1.8
Alumina, Al ₂ O ₃	2.3	Chlorid, Cl.....	15.0
Calcium, Ca.....	174.2	Alkalinity, Methyl Orange	394.0
Magnesium, Mg.....	62.1	Residue.....	912.0
Ammonia, NH ₄	.6		

The mineral content (calcium) of the water used in conducting the feathering tests it would seem from these data might have been suffi-

cient to disturb the calcium balance in the mixture of hot water and cream and cause coagulation of a part or all of the casein. This contention has been recently confirmed by Sommer.^{5*} It is also in agreement with the early work of Sommer and Hart,^{6*} who found the heat stability of the casein of evaporated milk to depend upon the proper balance of the calcium and magnesium salts and the citrates and phosphates, a slight excess of either group resulting in a lowering of the heat coagulation point of the casein. They report that this balance in the case of evaporated milk is a rather delicate one. That the same principle holds true for cream feathering is evidenced by the data in Table 1, which show the maximum proportion of hard water that it was possible in these experiments to use in a mixture of hard water and soft water without the cream feathering.

TABLE 1.—EFFECT OF MINERAL CONTENT OF WATER USED IN MAKING COFFEE ON FEATHERING OF CREAM*

Point where curdling occurred	Homogenizing pressure at 145° F.
<i>Perct. hard water</i>	<i>lbs.</i>
60-65	550
35-40	1 000
30-35	2 000
25-30	3 000

*Hard water was used in various proportions with soft water.

Further evidence which indicated the necessity for maintaining a proper salt balance in the cream and water mixture in order to avoid feathering was obtained by adding sodium citrate to the hard water used in conducting the feathering test. When .2 percent of this salt was added, no signs of feathering were apparent even when using cream that was homogenized at 3,000 pounds pressure, which feathered very readily when used with the hard water alone. It was also found that the addition of sodium citrate to the cream reduced the tendency to feather, whereas calcium chlorid added either to the cream or to the water caused an increased amount of coagulation.

Effect of Temperature at Which Cream Is Homogenized

Cream containing 18.07 percent fat, 26.01 percent total solids, and .13 percent acidity was heated to 145° F. and held for 30 minutes. A part was then homogenized at this temperature, various pressures being used with the single valve and the double valve. The temperature of the remaining cream was dropped and the homogenizing procedure which had been followed at 145° F. was repeated at 125° F. The results recorded in Table 2 show in every case more feathering in the cream homogenized at the lower temperatures.

TABLE 2.—RELATION OF HOMOGENIZING TEMPERATURE TO FEATHERING OF CREAM

Homogenizing temperature	First valve, total pressure	Second valve pressure	Percentage of curd (by volume) in 100 cc. of cream-and-water mixture
	<i>lbs.</i>	<i>lbs.</i>	<i>perct.</i>
125° F.....	500		16
145° F.....	500		7
125° F.....	1 000		23
145° F.....	1 000		18
125° F.....	2 000		34
145° F.....	2 000		30
125° F.....	3 000		34
145° F.....	3 000		34
125° F.....	2 000	500	18
145° F.....	2 000	500	9
125° F.....	3 000	500	27
145° F.....	3 000	500	23
125° F.....	3 000	1 000	23
145° F.....	3 000	1 000	15

Effect of Temperature to Which Cream Is Heated

Cream testing 21.98 percent fat, 29.49 percent total solids, and .15 percent acidity was heated to 125° F., and after being held for 15 minutes a portion was homogenized at pressures ranging from 500 to 4,000 pounds. The remaining cream was then heated to 145° F., held for 10 minutes, and another portion homogenized at the same range of pressures. This was repeated after heating the cream to 175° F. and holding for 5 minutes. The remainder was then cooled to 145° F. and samples were secured at the various pressures. The remaining cream was cooled to 125° F. and homogenized at the various pressures. The results of feathering tests are recorded in Table 3.

It is evident that the temperature to which the cream is heated, as well as the temperature at which it is homogenized, are important factors in the control of cream feathering. In these experiments the greatest feathering occurred when the cream was heated to and homogenized at 125° F. Webb and Holm^{11*} found that maximum stability resulted from preheating the cream at 80° C. (176° F.). The above data show that heating and homogenizing the cream at 175° F. removed all tendencies toward feathering. Cream preheated at 175° F.,

TABLE 3.—RELATION OF TEMPERATURE TO WHICH CREAM IS HEATED TO FEATHERING

Temperature		Extent of feathering at various pressures					
Maximum to which heated	At which homogenized	No pressure	500 pounds	1,000 pounds	2,000 pounds	3,000 pounds	4,000 pounds
125° F.	125° F.	None	Light +	Fairly heavy	Heavy	Heavy	Very heavy
145° F.	145° F.	None	None	Slight	Medium	Fairly heavy	Fairly heavy
175° F. ^a	175° F.	None	None	None	None	None	None
175° F.	145° F.	None	Light	Light	Light +	Medium	Medium
175° F.	125° F.	None	Light	Light +	Medium	Medium +	Medium +

*It was not deemed practical to study temperatures higher than 175° F., owing to the effect of such temperatures on the flavor of the cream.

but homogenized at a lower temperature, feathered some, but not so much as did cream which was homogenized at a corresponding temperature but which had not been preheated at a higher temperature.

Relation of Pressure to Feathering When Using Two-Stage Homogenizer

As the data in Table 2 indicate, the homogenizing pressure has an important bearing upon the degree of feathering. Further data are presented in Table 4. Cream containing 22.54 percent fat and

TABLE 4.—EFFECT ON FEATHERING OF CREAM WHEN INCREASING THE PRESSURE ON ONE VALVE AND LEAVING THE PRESSURE ON THE OTHER VALVE CONSTANT

Series	Homogenizing pressure			Curd
	1st valve	2d valve	Total	
	<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>	<i>perct.</i>
1.....	None	500	500	None
	500	500	1 000	None
	1 000	500	1 500	8.5
	2 000	500	2 500	13.5
2.....	500	None	500	None
	500	500	500	None
	500	1 000	1 500	10.0
	500	2 000	2 500	19.5
3.....	None	1 000	1 000	9.0
	500	1 000	1 500	10.0
	1 000	1 000	2 000	10.0
	2 000	1 000	3 000	11.5
4.....	1 000	None	1 000	9.5
	1 000	500	1 500	8.5
	1 000	1 000	2 000	10.0
	1 000	2 000	3 000	16.0
5.....	None	1 500	1 500	17.5
	500	1 500	2 000	16.0
	1 000	1 500	2 500	13.0
	2 000	1 500	3 500	20.0
6.....	1 500	None	1 500	16.0
	1 500	500	2 000	10.0
	1 500	1 000	2 500	9.0
	1 500	2 000	3 500	16.5

7.71 percent serum solids was used in these tests. The cream had a temperature of 135° F. at the time it was homogenized. Its acidity was .13 percent.

Keeping the adjustment on the first valve constant and increasing the pressure on the second valve to a point not to exceed the actual pressure on the cream as it passed thru the first valve, decreased feathering. When the pressure on the second valve was increased to the point where it equaled or exceeded the difference between the total pressure and that on the second valve, further increase on the second valve caused an increased amount of feathering. In the same way keeping the adjustment on the second valve constant and in-

creasing the actual pressure on the first valve to a point not to exceed the pressure on the second valve, decreased feathering. When the actual pressure on the first valve was increased to a point where it equaled or exceeded the pressure on the second valve, further increase in the actual pressure on the first valve caused an increased amount of feathering.

When using the two valves, more feathering resulted from those pressure combinations in which the low pressure was on the first valve than when the low pressure was on the second valve. This is shown by the following arrangement of data taken from Table 4.

Pressure on first valve	Pressure on second valve	Total pressure	Curd
<i>lbs.</i>	<i>lbs.</i>	<i>lbs.</i>	<i>perct.</i>
500	1,000	1,500	10.0
500	1,500	2,000	16.0
500	2,000	2,500	19.5
1,000	500	1,500	8.5
1,500	500	2,000	10.0
2,000	500	2,500	13.0
1,000	500	1,500	8.5
1,000	1,000	2,000	10.0
1,000	1,500	2,500	13.0
1,000	2,000	3,000	16.0
500	1,000	1,500	10.0
1,500	1,000	2,500	9.0
2,000	1,000	3,000	11.5

Composition of Cream a Factor

Using 40-percent cream pasteurized at 145° F. for 30 minutes, the following lots of cream were prepared:

1. 30-percent cream, standardized with pasteurized skim milk (145° F. for 30 minutes)
2. 20-percent cream, standardized with pasteurized skim milk (145° F. for 30 minutes)
3. 20-percent cream, standardized with pasteurized skim milk (145° F. for 30 minutes) and skim-milk powder
4. 20-percent cream, standardized with water (soft)

TABLE 5.—RELATION OF CREAM COMPOSITION TO FEATHERING

Sample No.	Material used to standardize cream	Fat	Solids- not-fat	Acidity	Curd
		<i>perct.</i>	<i>perct.</i>	<i>perct.</i>	<i>perct.</i>
1.....	Skim milk.....	29.86	6.77	.110	23.5
2.....	Skim milk.....	20.23	7.62	.120	14.0
3.....	Skim milk plus skim milk powder.	19.80	9.01	.155	2.0
4.....	Water.....	20.56	4.88	.075	17.5
5.....	Skim milk*.....	20.24	7.65	.120	14.5
6.....	Water*.....	20.22	4.86	.075	17.5

*Standardized from No. 1 after homogenizing.

These products were all heated to 140° F. and immediately homogenized at 2,000 pounds pressure. A part of the homogenized 30-percent cream was then used to prepare two additional lots of 20-percent cream as follows:

20-percent cream, standardized with pasteurized skim milk

20-percent cream, standardized with water (soft)

Results of feathering tests, together with the composition of the creams are recorded in Table 5.

As the fat was increased, the amount of feathering likewise increased. On the other hand, an increase in serum solids decreased the amount of feathering, and a decrease in the percentage of serum solids increased the amount of feathering. The extent of feathering of the cream that was homogenized before being standardized was the same as that of the cream of similar composition homogenized after being standardized.

DISCUSSION OF RESULTS

Two main factors apparently control the feathering of fresh homogenized cream: the calcium balance and the physical condition of the butterfat. A slight excess of calcium in either the cream serum or the water used in making the coffee may result in a casein precipitate in the presence of sufficient heat. The mineral content of the milk may vary enough to cause a calcium excess. The time in the lactation period and the feed of the cow may be partly responsible for the existence of such a condition. One investigator^{10*} has reported that cows at the beginning and at the end of the lactation period give milk containing a higher proportion of calcium to phosphorus. According to Sommer and Hart^{6*} the feed of the cows has no bearing upon the heat coagulation of milk. It has been reported by Hess *et al.*^{4*} that the citric-acid content of the milk is greater when the cows are on pasture. Results of one investigation^{7*} show that the type of soil on which cows are pastured has a bearing upon the readiness with which the curd is formed with rennet, the milk produced on limy soil requiring little rennet and producing a tough curd.

Preheating cream to high temperatures reduces feathering. This is due partly to the fact that high temperatures reduce the soluble calcium salts and this results in a decrease in the calcium excess. On the other hand, the calcium excess may be increased by an increase in acidity. The lactic acid reacts with the insoluble dicalcium phosphate (Ca H PO_4), changing it to the soluble monocalcium phosphate ($\text{Ca H}_4 (\text{PO}_4)_2$). This reaction takes place immediately with the formation of the acid, so that a slight acidity increase may cause feathering to occur.

Usually any treatment of the cream that causes the fat to clump or causes an increase in viscosity tends to increase feathering. Doan^{3*}

Heat

has shown that high temperatures tend to decrease fat clumping; which fact may partly explain why cream preheated at 175° F. feathered less than the same cream heated only to 145° F. before homogenizing. Homogenization increases the amount of protein adsorbed by the fat globules, which according to Titus *et al*^{8*} consists mostly of casein. Peculiarly, this localizing of the casein on the fat and the clumping of the globules makes the casein more susceptible to heat coagulation. Webb and Holm^{11*} suggest that this may be due to a variation of the potential upon the fat globules. It may be that thru molecular orientation^{2*} of the casein molecule in the adsorbed film, the stability of the protein in the presence of soluble calcium is lessened. It is also possible that the accumulation of the casein upon the fat globules removes from the field of reaction that casein which forms the innermost layer of the adsorbed film, especially that in the fat clusters, thus disturbing the balance existing between the remaining casein and the calcium in the serum. This balance is made more favorable by the presence of added serum solids.

TABLE 6.—EFFECT OF WHIPPING CREAM ON THE DISPERSION OF SERUM SOLIDS

Cream	Fat	Solids-not-fat	Calculated solids in serum	Proportion of total solids that are serum solids	Ratio of serum solids to fat
	<i>perct.</i>	<i>perct.</i>	<i>perct.</i>	<i>perct.</i>	
Original cream.....	20.90	7.83	9.9	26.90	1 : 2.67
Foam.....	34.72	11.24	17.21	24.43	1 : 3.09
Drain.....	17.20	7.78	9.39	31.12	1 : 2.22

When homogenized at temperatures near the solidifying point of the fat, greater clustering results. This possibly accounts for the greater feathering of cream homogenized at low temperatures. The use of the second stage usually breaks up the fat clusters, resulting in less feathering.

Inasmuch as fat clustering occurs when cream is whipped, it might be expected that if cream feathering were to be explained thru fat clumping alone, cream would feather more after being whipped than before. However, the reverse is true and, if allowed to stand, both the foam and the drain that forms will feather less than the original cream. In the case of the whipped cream, air dispersed thru the fat and serum apparently acts as a protection to the adsorbed casein, enabling it to mix into the serum and hot water in such a way as to result in less coagulation.

A study of the composition of the foam and drain from a lot of whipped cream, as well as that of the original cream, is of interest

in seeking a possible explanation for the differences in the feathering of these three products. These data are recorded in Table 6.

The reduced feathering of the foam may be partially explained as being due to the presence of an excess amount of serum solids, this condition tending to offset the slight calcium excess that exists in the cream-and-water mixture. The increased proportion of serum solids to fat probably accounts for the reduced feathering of the drained portion.

SUMMARY

An attempt has been made to show that cream feathering represents a type of reaction similar to that of the curdling of evaporated milk.

An excess of calcium in either the cream or the water used in making the coffee was found to produce feathering. Cream of high quality homogenized at a low pressure (500 pounds) sometimes feathered when water was used that contained as much as 174 parts of calcium per million. Creams high in butterfat feathered more than those containing a smaller percentage of the fat. The addition of serum solids in the form of skim-milk powder reduced the amount of feathering. Factors that result in a greater viscosity or increased clumping of the fat generally caused more feathering. Cream preheated at 175° F. feathered less than cream preheated at 145° F. There was likewise less feathering in cream homogenized at the higher temperatures. There was more feathering in cream homogenized at high pressures. The use of the second stage on the homogenizer in some cases reduced the amount of feathering. When a two-stage homogenizer was used, best results were obtained when using the low pressure on the second stage; and as the difference between the initial pressure on the first valve and that on the second valve was reduced, the amount of feathering was lessened.

CONCLUSIONS

Factors contributing to the feathering of fresh cream in coffee are:

1. Presence of soluble calcium salt in water used in making the coffee.
2. Excess of soluble calcium salts in cream.
3. Preheating at temperatures less than 175° F.
4. Increasing the proportion of fat to serum solids in the cream.
5. Increasing the surface of the fat adsorbing area in the cream thru increased homogenizing pressures.
6. Using single homogenization rather than double, or using an improper combination of pressures when using the two-stage machine.
7. Increasing cream viscosity thru homogenization at low temperature.

The feathering of fresh cream in coffee may be controlled as follows:

1. In making coffee use water that has a low calcium content.
2. When an epidemic of feathering occurs, add sodium bicarbonate, sodium citrate, or disodium phosphate (if the state law permits the addition of these constituents to coffee cream) in the amounts found necessary to prevent the feathering. Ordinarily 8 to 20 ounces of these salts to 1,000 pounds of cream will be sufficient.
3. Pasteurize the cream by heating at 155° F. for 30 minutes. Raise the temperature to 165° F., cool to 145° F. and homogenize.
4. If using a single-stage machine, homogenize at 500 to 1,000 pounds pressure. If using a two-stage machine, homogenize at a total pressure of 1,500 to 2,500 pounds with a pressure of 500 to 1,000 pounds on the second valve. The initial pressure on the first valve should be not more than 500 pounds greater than that on the second valve.
5. A daily laboratory test should be run on each batch of coffee cream before bottling. This test can be easily performed by placing 9 or 10 grams of the cream in a coffee cup and adding enough water from the local supply at a temperature of 200° to 212° F. to fill the cup. If no feathering occurs, the cream can be safely marketed.

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BULLETIN. URBANA

338-353 1929-30



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